

What Determines the Resistance and the Tilt of an Aeroplane?¹

By Sir JOSEPH LARMOR, F.R.S.

ONE used to recognise that the exigencies of flight in the tenuous air prescribed a limit to the bulk of a bird, as compared for example with a whale. Yet nowadays every day loads of twenty tons of stuff or possibly far more are carried over long journeys, owing to the power available, solely on wings. How does the attenuated aerial medium find means of supporting such an astonishing mass? To experts the fact is familiar, and so scarcely demands explanation. Indeed, the source of the support in plain terms is just as wonderful as the fact itself. The load is held up solely by the swirl that it produces and leaves behind, and this vortical support must be the only dynamical effect of the swirl when the speed is steady: there remains the question how precisely this result is adjusted. Unfortunately the wakes from screw and wings can scarcely be additive without some mutual interference, though momenta are additive always. For example the spread of the wings is adapted readily to counteract the rotational grip of the screw. Stability is theoretically (G. H. Bryan) another affair.

Whether the supporting medium is air, or water, or even pitch, provided only it is of uniform density everywhere, the momentum, with which the flight is concerned, proves to be expressible at each instant in terms of the distribution of swirl or vorticity alone. Force is experienced by the travelling system equal and opposite to the rate at which momentum is shed away into the wake of its motion. The nature of the swirl passing into the wake thus determines all. In the ideal perfect fluid of abstract hydrodynamics there would be no wake, and therefore no force affecting the translatory motion, though the mass may twirl in permanent precessional spin. If this train of ideas is

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right it is impossible for a circulation round the wings of an aeroplane to sustain it, except in so far as it has to be associated with a vortical wake.

The formula for the momentum associated with each element of whirl in the ambient medium, of whatever kind it be and however complex its internal friction, provided only it is of *uniform density*, turns out to be unexpectedly simple. There is translational momentum equal, as applied at any chosen origin, to the vector moment of the mass-vorticity of the element (mass multiplied by spin), combined with rotational momentum around that origin equal to this mass-vorticity multiplied by the square of the distance with sign reversed. Now vorticity has the advantage of being a quality of considerable persistence, unless the internal friction is high: if then this field of spin could be sufficiently explored by observation, it would only be necessary, in order to obtain the forces operating, to trace out the rate at which the derived system of momentum thus associated with the travelling machine is changing. Many special illustrations present themselves. For example, a travelling aeroplane adjusts its presentation so that this moment of momentum, with regard to the point where the pull of the screw intersects the line of weight, is not subject to loss into the wake: such automatic adjustment would tend to nip together the two boundary sheets of the vortical trail, which thus would open out only at the ends of the wings. Again, a windmill parachute appears to be more effective than the simple umbrella type: if so, the cause doubtless declares itself in a wind-channel by the contrasted types of whirl in the wakes they leave behind. And generally, the performance of any propelling screw wholly submerged would be determinable in terms of the whirl in its wake alone, if only that could be explored.

The Wren-Ashmole-Plot Memorial Windows at Oxford.

THE public unveiling of the memorial windows to Sir Christopher Wren, Ashmole, and Dr. Plot by the Chancellor of the University, Lord Cave, took place at Oxford on May 17 in ideal circumstances of weather, after the ceremony of the presentation of honorary degrees to MM. Doumergue and Briand. Speeches were delivered in the Divinity School by the representatives of the bodies who have given the windows. Mr. Madan, on behalf of Brasenose College, spoke on Ashmole as the founder of the oldest museum of natural history; Mr. Guy Dawber, president of the Royal Institute of British Architects, pronounced an éloge on Wren; and the Public Orator, Mr. Poynton, representing University, Magdalen, and Hertford Colleges, made a witty speech on Dr. Plot. The windows are a notable addition to the beauty of the staircase of the Old Ashmolean Museum, and will recall to generations of visitors the great pioneer work of this interesting group of men of science of the seventeenth century, some of whose work is illustrated in the Lewis Evans Collection on the upper floor of the building. The Chancellor expressed the grateful thanks of the University to the respective donors. He also paid a well-deserved tribute to Dr. R. T. Gunther, the Curator of the Lewis Evans Collection of Scientific Instruments, to whose zeal and energy are to be attributed the excellent arrangement and appropriate housing of the Lewis Evans Collection, and at whose instigation the donors of the memorial windows were moved to undertake these admirable

additions to the interest of the historic building that contains them.

The new windows in the Old Ashmolean Building commemorate the work of Ashmole and his three friends, whose collective scientific achievements during the second half of the seventeenth century have proved second to none even in that fertile period of English science. The word collective is used designedly, for it is extremely probable that the labour or good intention of any one member of the group would have been of no avail without the faithful co-operation of the others. They have one and all in their several ways participated in the establishment in Oxford of the first public museum of natural history in Britain. It is meet that so great a public service should be recognised in the building, which fortunately is still standing, a monument to their great work.

The oldest member of the group, John Tradescant, was a great collector, a scientific traveller, a pioneer who introduced new plants into Europe, and followed his father as the owner of the first London museum, at Lambeth. To him succeeded Elias Ashmole, a great transmitter. He realised the supreme educational value of the collection, and on the death of Tradescant, saved it from being scattered by his widow. His social prestige assured its appreciative acceptance by the University, which received the gift with royalty and a banquet, after the expending of a great sum on a building which is not only the finest classical building

in Oxford, but preserves to us Wren's plan for a scientific institution.

With singular appropriateness Oxford is therefore able to accept this memorial window to one of her most distinguished sons of science from the Royal Institute of British Architects. For long before the chance of rebuilding London definitely turned the scientific worker into the architect, Wren had filled the highest scientific post in the University with laudable distinction, and when the Ashmolean Museum was in building he occupied the presidential chair of the Royal Society.

The Tradescant window was presented by the Garden Clubs of Virginia in memory of his great prestige as a gardener and of his fruitful visits to their colony. It was unveiled by Lord Fairfax of Cameron in November last. The Ashmole window is given by the principal and fellows of Brasenose College, of which Ashmole was a member during his sojourn in Oxford. The badge and supporters to the coat of arms, the head of Mercury and the figures of the constellation of the Twins, are emblematic of Ashmole's double interest in astrology and alchemy, with especial regard to Mercury, planet and chemical element. The design has been taken from one of his most treasured books now in the Bodleian Library.

The inscription runs :

ELIAE ASHMOLE
HUIUS MUSEI FUNDATORI
COLL. AEN. NAS. PRINCIPALIS ET SOCI
ALUMNO SUO HANC FENESTRAM DEDICAVERT
MCMXXV.

The right-hand upper light records the distinguished service of Ashmole's first Keeper of the Museum, Dr. Robert Plot, one of the most remarkable of the Oxford celebrities of his time. He received his early education at University College, whence he proceeded to Magdalen Hall, and when thirty-seven years of age published his "Natural History of Oxfordshire," the work which not only made him famous but also probably suggested Oxford as the best destination for the Tradescant-Ashmole collections. His "Natural History" certainly was the first of its kind, and became the model for many later works. On the strength of a testimonial from John Evelyn, Ashmole in 1683 appointed Plot as his first Keeper of the Museum, a position that he filled for seven years, combining the duties with those of professor of chemistry and of secretary to the Philosophical Society of Oxford.

Towards the end of his life, Plot, elected to the office of Mowbray Herald, seems to have adopted the coat of arms in the new window. The surrounding wreath is of two Oxfordshire flowers which Plot was the first to recognise as new to the British flora. They are the marsh violet (*Viola palustris*) and the "Greatest Dove's foot Crane's-bill with dissected leaves" (*Geranium dissectum*). The happy dedicatory inscription runs :

ROBERTUS PLOT R.S.S.
HUNC CELEBRANT COLLEGIA NOMEN ET ARTEM
TRADITA MUSEI EST PRIMO CUSTODIA PRIMI.

In the right-hand lower light are emblazoned the arms and crest of Sir Christopher Wren, with two swags of foliage and contemporary scientific instruments familiar to astronomers and navigators at the time when, as Savilian professor of astronomy, Wren doubtless taught their theory to his pupils. The instruments comprise the mariner's astrolabe, cross-staff, backstaff, astronomical ring dial, and nocturnal, all very carefully studied and drawn upon the glass. Of special interest is the drawing of Wren's own pair of compasses,

now in the possession of the Royal Society, and the only example of his many instruments that has come down to us. A cartouche below contains the dedicatory inscription recording the circumstances of the presentation of this window by the Royal Institute of British Architects.

CHRISTOPHERUM WREN

ASTRONOMIAE PROFESSOREM SAVILLIANUM
COELESTIBUS EXSTRUCTIONIBUS NOBILEM COMMORAVIT
REGALIS SOCIETAS ARCHITECTORUM BRITANNICORUM
MCMXXVII

In a letter to the *Times* for May 23, the anniversary of Ashmole's birthday, Mr. E. B. Knobel expresses the hope that these armorial windows may be supplemented by one to Dr. Lewis Evans, whose gift has led to the revival of the Old Ashmolean.

University and Educational Intelligence.

CAMBRIDGE.—Dr. G. F. C. Searle, Peterhouse, has been reappointed University lecturer in experimental physics, and Mr. C. Warburton, Christ's College, has been reappointed demonstrator in medical entomology.

LONDON.—At a meeting of the Senate on May 18, the Vice-Chancellor stated that with reference to the anonymous offer, already announced, of £10,000 towards the establishment of a chair of dietetics, Messrs. A. Wander, Ltd., had now intimated their desire to contribute a similar sum to the same object.

It was announced that a donor who desires to remain anonymous has offered £250 as a contribution towards any preliminary expenses involved in the preparation of a comprehensive plan for the development of the Bloomsbury site.

Mr. D. MacC. Blair, lecturer in regional anatomy in the University of Glasgow, has been appointed as from Aug. 1 to the University chair of anatomy tenable at King's College.

Dr. G. S. Wilson has been appointed as from Oct. 1 to the University readership in bacteriology and immunology tenable at the London School of Hygiene and Tropical Medicine. Dr. Wilson was educated at Epsom College, King's College, London, and Charing Cross Hospital. In 1919 he was appointed specialist in bacteriology at the Royal Army Medical College; in 1921 he became assistant in bacteriology under the Medical Research Council. In 1923 was appointed lecturer in bacteriology in the University of Manchester, and since 1925 he has been assistant director of the Public Health Laboratory, Manchester.

The following doctorates were conferred: D.Sc. in Botany on Mr. P. Sarbadhikari (Imperial College—Royal College of Science) for a thesis entitled "Cytology of *Osmunda* and *Doodia*—On the Gametophyte and Post-meiotic Mitoses of the Gametophytic Tissue of *Doodia*;" and D.Sc. (Economics) on Mr. G. C. W. C. Wheeler (London School of Economics) for a thesis entitled "Mono-Alu Folklore."

The Dunn Exhibitions in anatomy and physiology were awarded to Mr. K. M. Robertson, of St. Thomas's Hospital Medical School.

THE Society for the Advancement of the Training of Mechanics, Leyden, announces vacation courses for mechanics and glassblowers in August next at the Physical (Cryogenic) Laboratory of the University of Leyden. Full particulars can be obtained from Dr. C. A. Crommelin, the Physical Laboratory, Leyden, Holland.

By the will of Lady (Charles) Henry, of Carlton Gardens, London, S.W., a large sum of money will become available for the foundation of scholarships